Typhoon-Ocean Interaction: The Ocean Response to Typhoons, and Its Feedback to Typhoon Intensity – Synergy of Observations and Model Simulations

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LONG-TERM GOALS

[top-level goals]

1. Measuring the response of the upper ocean to strong typhoons (including surface waves, air-sea fluxes, temperature, salinity, and velocity structure) both in simple, open ocean conditions and in the more complex conditions caused by ocean eddies, the Kuroshio and complex, shallow bathymetry.

2. Understanding key upper ocean precesses, validating the simulation of upper ocean models, testing key parameterizations of upper ocean physics used in these models, and studying the feedback from the ocean to typhoon intensity.

OBJECTIVES

[scientific or technological objectives]

1. Investigation of the roles of upper-ocean thermal structures (eddies and wakes) on typhoon-ocean interaction.

2. Understanding the feedback of the typhoon-ocean interaction to typhoon intensity and structure evolution.

3. Conducting real-case numerical simulation experiments (WRF-PWP coupled model) with the T-PARC (DOTSTAR, TCS-08, TCS-10) and ITOP data.

4. Monitoring of forming storms in the Pacific ocean to predict the track and strength in order to determine the optimal location for the aerial deployment of the drifters, floats and AXBT, as well as the best way for the ships based scientist to study the cold wake after the storm.

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APPROACH

[technical approach, key individuals]

Following the success of T-PARC in 2008, ITOP is the next important major field program in 2010 to take special observations to improve the understanding of typhoon-ocean interaction. With our experiences on targeted observations in DOTSTAR and T-PARC, and with our capability in conducting advanced data assimilation (EnKF) to both typhoon models and typhoon-ocean coupled models, we can further conduct high resolution typhoon-ocean coupled model experiments, along with the use of the ITOP data, to have a comprehensive study to address the key typhoon-ocean interaction issues.

WORK COMPLETED

[tasks completed, technical accomplishments]

Though we have not received funding yet, the early work about impact of the upper-ocean thermal structure (UOTS) on typhoon intensity change was done. A comprehensive full-physics coupled atmosphere-ocean model (Chen et al. 2007) based on WRF model and 1-D PWP upper-ocean model (Price et al. 1986) is used to simulate Typhoon Sinlaku (2008), the case with special and significant oceanic features (Fig. 1). Besides, in the case of Sinlaku, unprecedented dropwindsonde data were obtained from four airplanes during T-PARC. In order to have a reasonable initial storm structure and intensity, a new method of TC initialization based on ensemble Kalman filter (EnKF) (Wu et al. 2010) is applied before we conduct the coupled model simulation. The high-resolution sensitivity experiments with different initial ocean mixed layer depth (ML) are performed to identify the role of ML on TC intensity in the coupled model. The experiments with cold eddies are also conducted to quantitatively evaluate the impact of cold eddies on the intensity change of Typhoon Sinlaku.

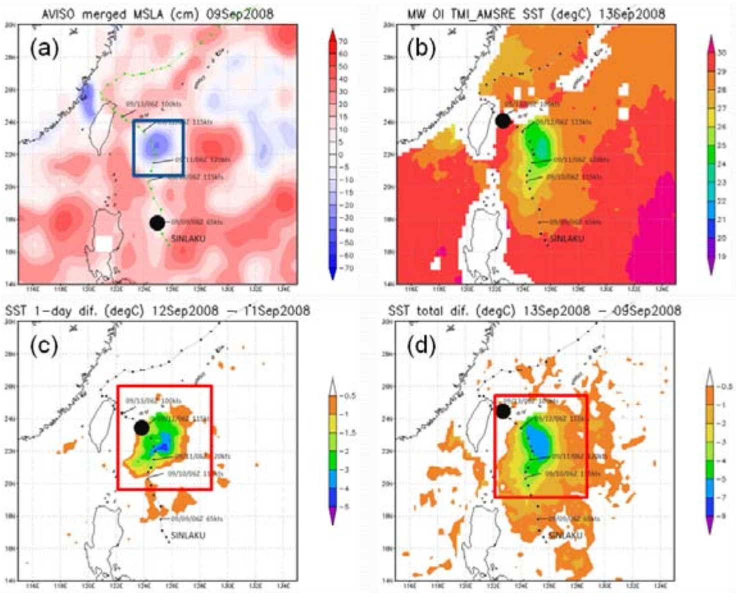

Fig. 1: The oceanic features of Typhoon Sinlaku (2008). (a) The SSHA (from AVISO merged mean sea level anomaly data; unit: cm) before the passage of Sinlaku (9 September). (b) The SST (from

TMI and AMSR-E; unit: °C) after the passage of Sinlaku (13 September). (c) The SST difference between 12 and 11 September. (d) The SST difference between 13 and 9 September.

Suitable matrices are developed to quantitatively evaluate the impact of UOTS on the intensity change of Sinlaku. The SST feedback factor and the ML feedback factor are calculated to quantitatively assess the effect of ocean cooling and different ML. The modified eddy feedback factors are also calculated to investigate the impact of cold eddies on SST feedback and the intensity of Sinlaku. Besides, a new MPI-related factor is defined to estimate the contribution of UOTS which would prevent Sinlaku from reaching MPI.

RESULTS

[Describe meaningful technical results achieved in the report fiscal year. Make the significance clear. Emphasize what was learned, not what was done. This should be a summary of significant results and conclusions, and, especially, any "new capabilities" generated.]

A new method of TC initialization based on EnKF data assimilation is applied in this study. The center, translation speed, and axisymmetric surface tangential wind profile of Sinlaku are assimilated in the model (Fig. 2) before we conduct the coupled model simulation. After 30-hour initialization based on EnKF, a reasonable initial storm structure and intensity close to observations are constructed. At the final time of initialization (0600 UTC 9 September), the position of Sinlaku is very close to JTWC best track data. Besides, both the simulated central pressure (about 974.8 hPa) and the maximum wind speed (about 30 m s^{-1}) of Sinlaku are very close to JTWC best track data (not shown).

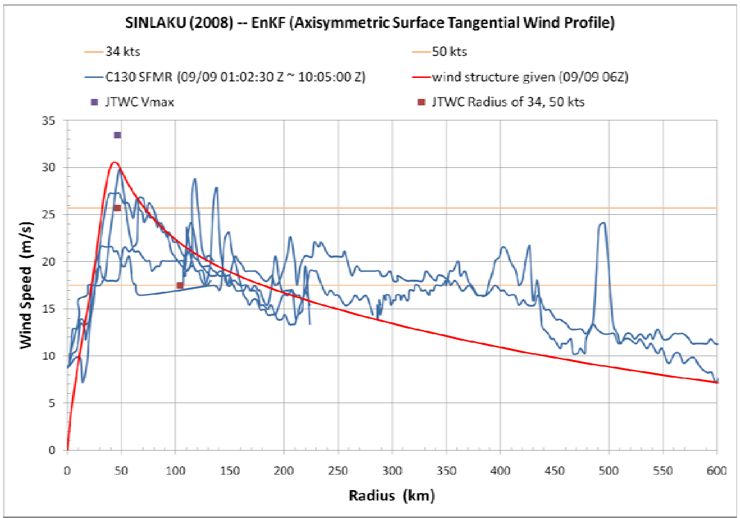

Fig. 2: The axisymmetric surface tangential wind profile assimilated in the model (red line) at 0600 UTC 9 September (the last time of initialization and the initial time of coupled model simulation), which is based on the observation of C-130 SFMR (blue line). The purple square represents the maximum sustained wind speed of JTWC best track data. The brown squares represent the radii of 34-kts and 50-kts wind.

The simulated track of Sinlaku in the uncoupled control run and the coupled control run are both close to JTWC best track data. In addition, the intensity of Sinlaku in the coupeld run and the uncoupled run are compared, and the SST feedback factor is calculated to quantitatively evaluate the impact of SST

feedback on the intensity of Sinlaku. After the translation speed of Sinlaku decreases and significant SST cooling is induced, the central pressure of Sinlaku in the coupled run begins to be higher than that in the uncoupled run (Fig. 3). It is shown that the SST feedback factor decreases with time, and gets the minimum of -0.4 (Fig. 4). It means that the intensity of Sinlaku in the coupled run is weaker than that in the uncoupled run by as much as 40%. The intensity change of Sinlaku in the coupled run is closer to JTWC best track data than in the uncoupled run.

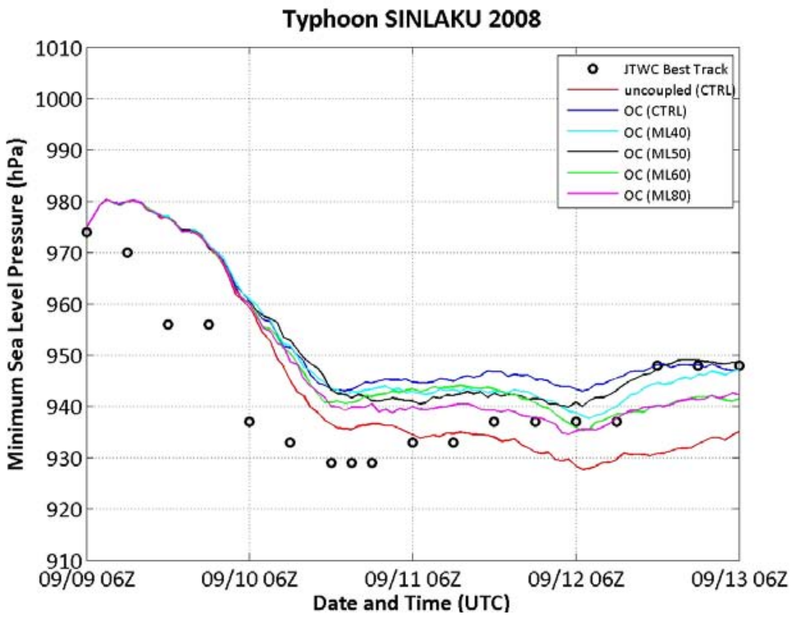

Fig. 3: The simulated central pressure of Typhoon Sinlaku in control runs and the experiments with different initial mixed layer depth (ML). The dark blue line is the control run with SST feedback, and the red line is the control run without SST feedback. The black circles are the central pressure of JTWC best track. The light blue, black, green, and pink lines represent the experiments with the initial ML of 40 m, 50 m, 60 m, and 80 m, respectively.

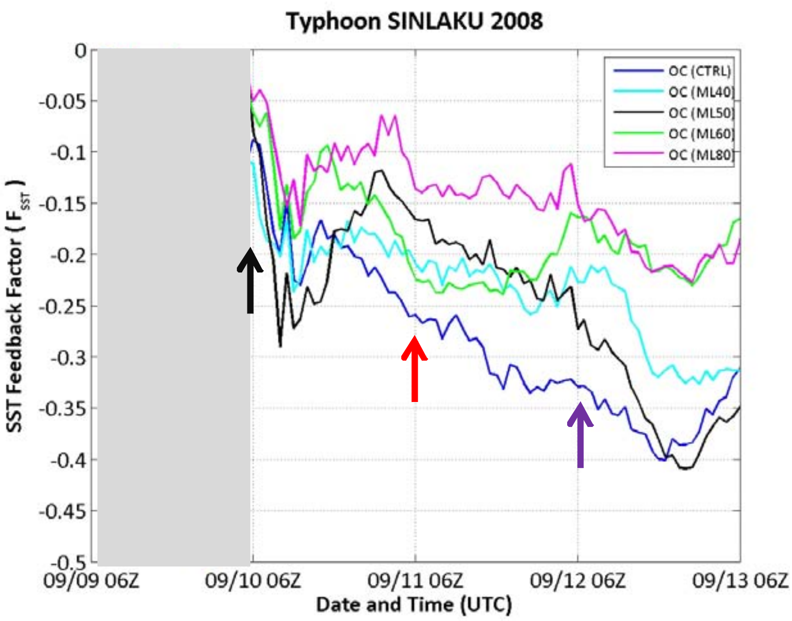

Fig. 4: The SST feedback factor (F_{SST}) in the control run (dark blue line) and the experiments with different initial mixed layer depth. The light blue, black, green, and pink lines represent the experiments with the initial ML of 40 m, 50 m, 60 m, and 80 m, respectively.

The results of sensitivity experiments with different initial ocean mixed layer depth are compared. After the SST feedback becomes strong, the intensity of Sinlaku in OC (ML80) run, the experiment with the deepest initial ML, begins to be stronger than that in other runs (Fig. 3). However, the relationship between the intensity of Sinlaku and the initial ML is not clear in the other runs (Fig. 3). In OC (ML80) run, the SST feedback is weaker (the absolute value of SST feedback factor is only 0.15 on 11 September and 0.2 on 12 September) than that in the other experiments with shallower initial ML (Fig. 4).

The ML feedback factor is defined to quantitatively evaluate the effect of thicker warm ocean layer, and a new MPI-related factor is defined to estimate the contribution of UOTS which would prevent Sinlaku from reaching MPI. In OC (ML80) run, the ML feedback factor is about 0.3 on 11 and 12 September, which is larger than that in the other runs with shallower initial ML (Fig. 5). It means that there is stronger impact of warm ocean layer in OC (ML80) run, and the intensity of Sinlaku is stronger than that in the coupled control run with climatological initial ML. Besides, the ocean contribution factor in OC (ML80) run is smaller than that in the other ML runs (Fig. 6). It is shown that the contribution of ocean which would prevent Sinlaku from reaching MPI in OC (ML80) run is less than that in the other ML runs, and the difference is about 10%.

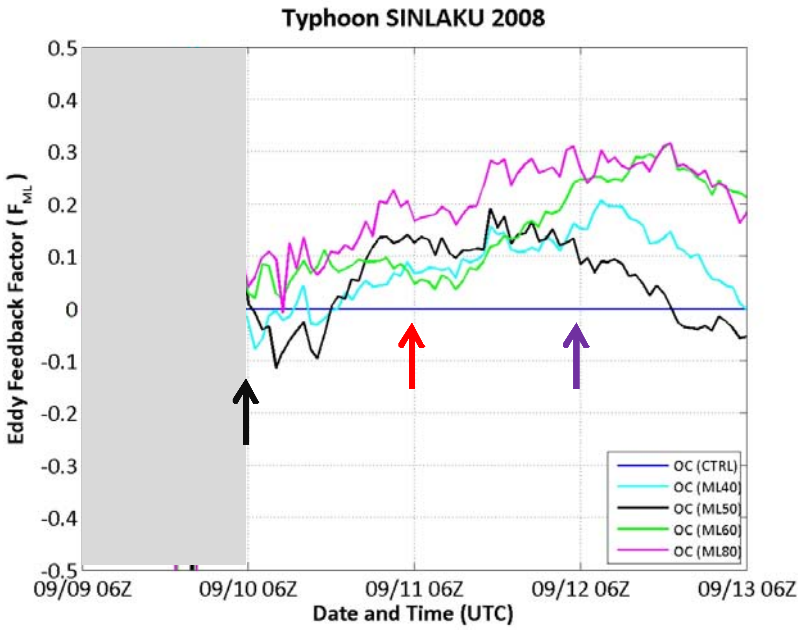

Fig. 5: The ML feedback factor (F_{ML}) in the experiments with different initial mixed layer depth. The light blue, black, green, and pink lines represent the experiments with the initial ML of 40 m, 50 m, 60 m, and 80 m, respectively.

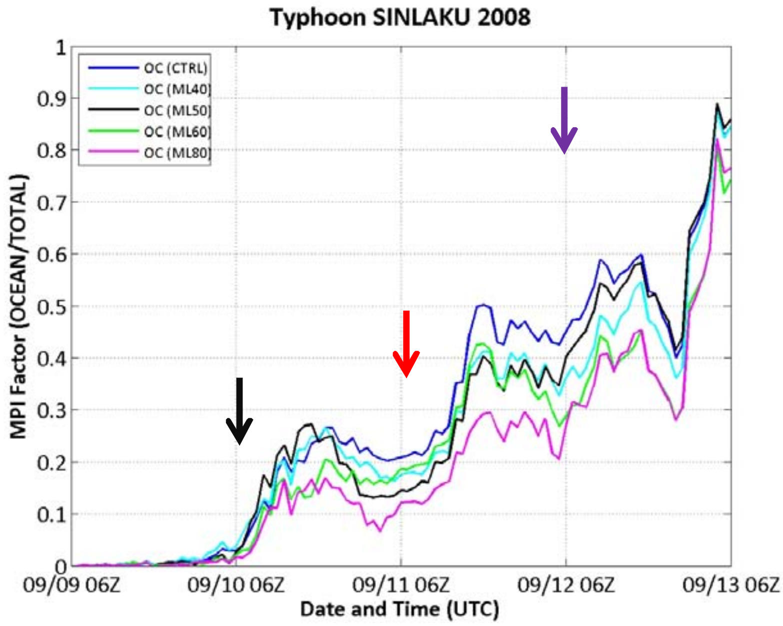

Fig. 6: The ocean contribution factor (F_{OC}) in the control run (dark blue line) and the experiments with different initial mixed layer depth. The light blue, black, green, and pink lines represent the experiments with the initial ML of 40 m, 50 m, 60 m, and 80 m, respectively.

The intensity of Sinlaku in the experiments with and without cold eddy are compared. The modified eddy feedback factors are calculated to investigate the impact of cold eddies on SST feedback and the intensity of Sinlaku. In OC (ML80CE) run, the storm intensity decreases by about 15% when Sinlaku passes a cold eddy, and 80% of the intensity change in this period is likely due to the presence of cold eddy. In OC (ML60CE) run, the storm intensity decreases by about 7% when Sinlaku passes a cold eddy, while Sinlaku intensifies in the same period in the simulation without cold eddy.

IMPACT/APPLICATIONS

[Potential future impact for science and/or systems applications]

From the results of this study, we believe that synergy of TC initialization based on EnKF data assimilation and a coupled atmosphere-ocean model can help us quantitaively evaluate the impact of UOTS on TC intensity. More typhoon cases could be simulated and analyzed with the method used in this study, and the impact of UOTS in different atmospheric environments could be investigated in follow-up research. In addition, results from this study would set up a solid basis for the follow-up researches with the field program of ITOP in 2010. It would be a good chance to use in-situ ocean data to validate the results of coupled model simulation.

TRANSITIONS

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RELATED PROJECTS

{IF NONE, so state}

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PUBLICATIONS

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[(‘refereed’ or significant non-refereed), books, or chapters; submitted, ‘in press’, or published. Do Not list papers in preparation or development.]

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